

FORM PTO-1390US DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE (REV 5-93)		ATTORNEY'S DOCKET NUMBER 9052-70
TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371		U.S. APPLICATION NO. (If known, see 37 C.F.R. 1.5) <b>09/701775</b>
INTERNATIONAL APPLICATION NO. PCT/GB99/01537	INTERNATIONAL FILING DATE June 3, 1999	PRIORITY DATE CLAIMED June 3, 1998
TITLE OF INVENTION <i>APPARATUS FOR DISSOLVING NUCLEAR FUEL</i>		
APPLICANT(S) FOR DO/EO/US Leonid Solomonovich RAGINSKII; Vyacheslav Evgen'evich MORKOVNIKOV; Nikolai Viktorovich MOROZOV; Sergei Petrovich ELISEEV; Peter RANCE; Timothy TINSLEY; Iain DENNISS		
Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:		
<ol style="list-style-type: none"> <li>1. <input checked="" type="checkbox"/> This is a <b>FIRST</b> submission of items concerning a filing under 35 U.S.C. 371.</li> <li>2. <input type="checkbox"/> This is a <b>SECOND</b> or <b>SUBSEQUENT</b> submission of items concerning a filing under 35 U.S.C. 371.</li> <li>3. <input checked="" type="checkbox"/> This express request to begin national examination procedures (35 U.S.C. 371(f)) at any time rather than delay examination until the expiration of the applicable time limit set in 35 U.S.C. 371(b) and PCT Articles 22 and 39(I).</li> <li>4. <input checked="" type="checkbox"/> A proper Demand for International Preliminary Examination was made by the 19th month from the earliest claimed priority date.</li> <li>5. <input checked="" type="checkbox"/> A copy of the International Application as filed (35 U.S.C. 371(c)(2)) <ol style="list-style-type: none"> <li>a. <input checked="" type="checkbox"/> is transmitted herewith (required only if not transmitted by the International Bureau).</li> <li>b. <input type="checkbox"/> has been transmitted by the International Bureau.</li> <li>c. <input type="checkbox"/> is not required, as the application was filed in the United States Receiving Office (RO/US).</li> </ol> </li> <li>6. <input type="checkbox"/> A translation of the International Application into English (35 U.S.C. 371(c)(2)).</li> <li>7. <input checked="" type="checkbox"/> Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371(c)(3)) <ol style="list-style-type: none"> <li>a. <input checked="" type="checkbox"/> are transmitted herewith (required only if not transmitted by the International Bureau).</li> <li>b. <input type="checkbox"/> have been transmitted by the International Bureau.</li> <li>c. <input type="checkbox"/> have not been made; however, the time limit for making such amendments has NOT expired.</li> <li>d. <input type="checkbox"/> have not been made and will not be made.</li> </ol> </li> <li>8. <input type="checkbox"/> A translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).</li> <li>9. <input type="checkbox"/> An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).</li> <li>10. <input type="checkbox"/> A translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).</li> </ol>		
Items 11. to 16. below concern other document(s) or information included:		
<ol style="list-style-type: none"> <li>11. <input checked="" type="checkbox"/> An Information Disclosure Statement under 37 C.F.R. 1.97 and 1.98.</li> <li>12. <input type="checkbox"/> An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.</li> <li>13. <input checked="" type="checkbox"/> A FIRST preliminary amendment. <input type="checkbox"/> A SECOND or SUBSEQUENT preliminary amendment.</li> <li>14. <input type="checkbox"/> A substitute specification.</li> <li>15. <input type="checkbox"/> A change of power of attorney and/or address letter.</li> <li>16. <input type="checkbox"/> Other items or information: International Preliminary Examination Report.</li> </ol>		

U.S. APPLICATION NO (If known, see 37 C.F.R. 1.50) <div style="font-size: 2em; font-weight: bold; margin-top: 10px;">09/701775</div>		INTERNATIONAL APPLICATION NO PCT/GB99/01537		ATTORNEY'S DOCKET NUMBER 9052-70	
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17. <input checked="" type="checkbox"/> The following fees are submitted: <div style="margin-top: 10px;"> <b>Basic National Fee (37 CFR 1.492(a)(1)-(5)):</b>            Search Report has been prepared by the EPO or JPO . . . . . \$860.00             International preliminary examination fee paid to USPTO            (37 CFR 1.482). . . . . \$690.00             No international preliminary examination fee paid to USPTO            (37 CFR 1.482) but international search fee paid to USPTO            (37 CFR 1.445(a)(2)) . . . . . \$710.00             Neither international preliminary examination fee (37 CFR 1.482)            nor international search fee (37 CFR 1.445(a)(2)) paid to            USPTO. . . . . \$1,000.00             International preliminary examination fee paid to USPTO            (37 CFR 1.482) and all claims satisfied provisions of PCT            Article 33(1)-(4). . . . . \$100.00             ENTER APPROPRIATE BASIC FEE AMOUNT = \$860.00         </div>	CALCULATIONS	PTO USE ONLY																
Surcharge of \$130.00 for furnishing the oath or declaration later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	\$																	
<table border="1" style="width: 100%; border-collapse: collapse;"> <tr> <th style="width: 20%;">Claims</th> <th style="width: 20%;">Number Filed</th> <th style="width: 20%;">Number Extra</th> <th style="width: 40%;">Rate</th> </tr> <tr> <td>Total Claims</td> <td>25-20 =</td> <td>5</td> <td>X \$18.00</td> </tr> <tr> <td>Independent Claims</td> <td>2-3 =</td> <td>0</td> <td>X \$80.00</td> </tr> <tr> <td colspan="3">Multiple dependent claim(s) (if applicable)</td> <td>+ \$270.00</td> </tr> </table>	Claims	Number Filed	Number Extra	Rate	Total Claims	25-20 =	5	X \$18.00	Independent Claims	2-3 =	0	X \$80.00	Multiple dependent claim(s) (if applicable)			+ \$270.00	\$ 90.00	
Claims	Number Filed	Number Extra	Rate															
Total Claims	25-20 =	5	X \$18.00															
Independent Claims	2-3 =	0	X \$80.00															
Multiple dependent claim(s) (if applicable)			+ \$270.00															
TOTAL OF ABOVE CALCULATIONS =	\$950.00																	
Reduction by 1/2 for filing by small entity, if applicable. Verified Small Entity statement must also be filed. (Note 37 CFR 1.9, 1.27, 1.28).	\$																	
SUBTOTAL =	\$950.00																	
Processing fee of \$130.00 for furnishing the English translation later than [ ] 20 [ ] 30 months from the earliest claimed priority date (37 CFR 1.492(f)).	\$																	
TOTAL NATIONAL FEE =	\$950.00																	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). \$40.00 per property +	\$																	
TOTAL FEES ENCLOSED =	\$950.00																	
	Amount to be refunded \$																	
	charged \$																	

a. ☒ A check in the amount of **\$950.00** to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. \_\_\_\_\_ in the amount of \$ \_\_\_\_\_ to cover the  
 above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any  
 overpayment to Deposit Account No. 50-0220.

**NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must  
 be filed and granted to restore the application to pending status.**

SEND ALL CORRESPONDENCE TO:

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Marjorie J. Pfeiffer  
 Date of Signature: December 1, 2000

SIGNATURE  
  
 Robert J. Smith  
  
 40,820  
 REGISTRATION NUMBER

09/701775

525 Rec'd PCT/PTO 01 DEC 2000

Attorney's Docket No. 9052-70

PATENT

IN THE UNITED STATES DESIGNATED OFFICE (DO/US)

In re: Application of Raginskii et al.  
Serial No.: To be Assigned  
Filed: Concurrently Herewith  
For: *APPARATUS FOR DISSOLVING  
NUCLEAR FUEL*

Date: December 1, 2000

BOX PCT  
Commissioner for Patents  
Washington, DC 20231

PRELIMINARY AMENDMENT

Sir:

Prior to the examination of the above application and calculation of claim fees,  
please amend the above-identified application as follows:

In the Specification:

Please add the following abstract subsequent to the claims.

Abstract of the Disclosure

A nuclear fuel dissolution apparatus which comprises a perforated sloping ramp contained within a process chamber for containing solvent for the fuel, a pulsation member which in use creates pulses in solvent in the process chamber, the perforations being designed to direct pulses of solvent along and up the ramp, and a discharge point for fuel hulls disposed at an upper region of the ramp is characterised in that the ramp is made out of flat blades and the perforations of the ramp comprise inclined slits formed between the blades.

In the Claims:

1. (Amended) A nuclear fuel dissolution apparatus which comprises a perforated sloping ramp **[(19)]** contained within a process chamber **[(1)]** for containing solvent for the fuel, a pulsation member **[(9)]** which in use creates pulses in solvent in the process chamber **[(1)]**, the perforations **[(7)]** being

designed to direct pulses of solvent along and up the ramp **[(19)]**, and a discharge point **[(18)]** for fuel hulls disposed at an upper region of the ramp characterised in that the ramp **[(19)]** is made out of flat blades **[(6)]** and the perforations **[(7)]** of the ramp **[(19)]** comprise inclined slits formed between the blades **[(6)]**.

In Claim 2, line 1, please delete "(19)".

In Claim 3, line 1, please delete "or claim 2" and "(1)".

4. (Amended) An apparatus of claim 1 **[any of claims 1 to 3]** in which the gradient of the spiral is between 1 and 30 degrees.

6. (Amended) An apparatus of claim 1 **[any of claims 1 to 5]** in which the gradient of the spiral in an upper zone thereof is greater than in a lower zone.

In Claim 8, line 1, please delete "or claim 7".

9. (Amended) An apparatus of claim 1 in which the blades **[(6)]** are made in the form of a trapezium and are fastened by the smaller end to a central blade support within the process chamber **[(1)]**.

In Claim 10, line 1, please delete "(6)".

12. (Amended) An apparatus of claim 1 in which the pulsation member **[(9)]** comprises a pulsation chamber disposed centrally within the process chamber **[(1)]**.

In Claim 13, line 2, please delete "(1)".

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Please cancel Claim 14.

15. (Amended) An apparatus for the treatment of solid articles by liquid, comprising a container having an outer side wall of circular cross section, a spiral ramp **[(19)]** located in the container, and a pulsator **[(9)]** communicating with a lower part of the container, and also pipe connections for feeding in and removing pieces of fuel pin, solution and gas, characterised in that the ramp **[(19)]** is made up of flat blades **[(6)]** placed one after another along the spiral and forming between one another inclined slit nozzles and the perforations **[(7)]** of the ramp comprise inclined slits between the blades **[(6)]**.

18. (Amended) An apparatus of claim 15 **[any of claims 15 to 17]** in which the angle between the plane of the blades and the horizontal plane is between 15 and 60 degrees.

19. (Amended) An apparatus of claim 15 **[any of claims 15 to 18]** in which the gradient of the spiral in an upper zone thereof is greater than in a lower zone.

20. (Amended) An apparatus of claim 15 **[any of claims 15 to 19]** in which the blades **[(6)]** are made in the form of a trapezium and are fastened by the smaller end to a central blade support within the process chamber **[(1)]**.

21. (Amended) An apparatus of claim 15 **[any of claims 15 to 20]** in which the average width of the blades is between 3 and 5 times the distances between them.

22. (Amended) An apparatus of claim 1 [any of claims 15 to 21] in which the pulsation member comprises a pulsation chamber [(9)] disposed coaxially within the process chamber [(1)].

24. (Amended) A method according to claim 23 wherein the apparatus comprises a perforated sloping ramp [(19)] contained within a process chamber [(1)] for containing solvent for the fuel, and a pulsation member which in use creates pulses in solvent in the process chamber [(1)], the perforations being designed to direct pulses of solvent along and up the ramp, the method comprising loading solvent into the process chamber [(1)], loading fuel pin pieces onto a lower region of the ramp and creating solvent pulses to transport the fuel pin pieces up the ramp to a discharge point when the cladding hulls are discharged from the ramp.

#### REMARKS

Claims 1-25 are presented for examination and are included herewith as revised claims with the International Preliminary Examination Report. Claim 14 has been canceled. Various claims have been amended to better conform to U.S. practice. Applicants respectfully request substantive examination on the merits.

Respectfully submitted,

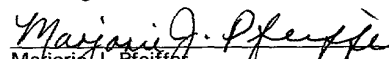


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Marjorie J. Pfeiffer  
Date of Signature: December 1, 2000

APPARATUS FOR DISSOLVING NUCLEAR FUEL

The present invention relates to the reprocessing of irradiated nuclear fuel and particularly the dissolution of nuclear fuel pins.

5

Nuclear fuel pins consist of pellets of fissile material, e.g.  $\text{UO}_2$ , contained in a cladding which is normally a zirconium alloy sold under the trade mark Zircaloy. A cluster of pins form a fuel assembly.

- 10 Commercial reprocessing of irradiated (spent) nuclear fuel uses the Purex process, which involves chopping up the pins of an assembly prior to dissolution of the fissile material in nitric acid. The pins must be chopped up to expose the pellets to nitric acid because the bulk zirconium alloy is resistant to attack by nitric acid, as is an oxide skin which irradiated zirconium alloy possesses. After the fuel has been dissolved the empty pieces
- 15 of cladding (hulls) and other residues of the structure of the fuel assembly are encapsulated and disposed of.

Commercial reprocessing plants contain dissolvers based on one of two principles: batch operation or continuous operation using an apparatus with rotating mechanical parts.

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- In a typical batch dissolver the fuel is sheared into a large basket which is immersed in the dissolver vessel. After the fuel has been leached, the basket is removed from the dissolver using a crane and then tipped to transfer the hulls and other debris to the encapsulation plant. This system requires extensive mechanical handling of the dissolver basket which
- 25 is heavy and needs a large amount of maintainable equipment in the shielded dissolver cell.

- Continuous dissolvers shear the fuel into the segments of a wheel which is rotated inside a large vessel. The existence of rotating parts is a disadvantage and limits the geometry that
- 30 can be adopted to a very large slab tank if the equipment is ever to be safe.

US 4246238 discloses a batch action apparatus comprising a container in which is placed a basket filled with pieces of fuel pins, and to which pipe connections are fitted to feed in and remove solutions and gas. A disadvantage of the apparatus is the complexity of the sealing arrangement when the fuel pin pieces are loaded into the basket and when baskets  
5 are discharged from the apparatus, as well as the difficulty of containing radioactivity. In addition, use of such apparatuses would considerably complicate process automation and increase the volumes of radioactive solutions.

US 4230675 discloses an apparatus which is used to make countercurrent contact between  
10 fuel pin pieces and leaching solution. The apparatus comprises an elongate cylindrical drum which rotates around its longitudinal axis and is divided by transverse partitions into a chamber for feeding in fuel pin pieces and removing solution situated at one end of the drum, and a chamber for exit of the cladding pieces and delivery of solution situated at the other end of the drum. Between these chambers there are several other chambers in which  
15 leaching of the fuel from the chopped cladding takes place. In each chamber there are elements which provide for movement of the fuel pin pieces on rotation of the drum. A disadvantage of the apparatus is the complexity of its design, and the presence of moving units and of units subject to intensive abrasive action caused by the fuel pin pieces. An apparatus of this design would therefore have a low level of reliability and require regular  
20 servicing and maintenance under conditions of high levels of radioactive contamination.

Moving away now from nuclear reprocessing, USSR author's certificate No 764698 discloses a mass-exchange device for solid phase treatment (primarily for the treatment of wood chips) which comprises a cylindrical casing inside which is a perforated helical  
25 ramp with a helical surface gradient of between 4 and 30 degrees. The perforations are in the form of apertures screened above and below by angled plates. Some of the apertures are fitted with nozzles protruding above the surface of the ramp. In a bottom part of the apparatus, which is separated from the annular container by a grid, there is a pulse generator. In use, solid particles are charged onto the ramp at its bottom end. Pulsed fluid  
30 from the pulse generator passes upwards through the apertures in the ramp and raises the solid particles above the ramp, creating a pulsing suspended layer in which the particles

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are processed by the fluid. The solid particles are moved upwards and discharged at the top of the ramp.

The apparatus of USSR author's certificate No 764698 could not be used with chopped nuclear fuel pins and is incompatible with a nuclear reprocessing plant. Amongst other things, chopped fuel pins have a diameter of between 8 and 20 mm, a length of between 25 and 100 mm and a weight of up to 70 g and would not be moved up the ramp of the apparatus as described

- 10 A pulsation device which is designed for dissolving nuclear fuel pins is known from EP-A-358354 which comprises a V-shaped duct connected to a pulsation chamber containing nitric acid. Pieces of chopped fuel pin are loaded into the free end of one arm of the V-shaped duct. Compressed air in the pulsation chamber maintains nitric acid in the duct at a level which immerses most of the chopped pieces. The air pressure in the pulsation chamber is periodically released, resulting in most of the nitric acid in the duct leaving it. Compressed air is then again applied to the nitric acid in the pulsation chamber, causing acid to pulse into the duct such that leached hulls in the outlet arm of the duct are pushed upward to a discharge duct through which they leave the V-shaped duct.
- 20 An advantage of this apparatus is the simplicity of its design and the absence of moving parts. A disadvantage of the apparatus is the small volume of its process chamber and the low output of a single unit, with pieces of fuel pin spending a long time in the apparatus, as is essential for dissolution of the fuel. This is because the diameter of the V-shaped duct is restricted for criticality reasons, and the depth of the layer of fuel pin pieces in the duct is limited by the requirement that the pieces must move along steadily in a curving duct. To ensure that the required time is spent by the fuel pin pieces in the solution, therefore, a cascade of apparatuses of this type installed one after the other in sequence would have to be used. This would considerably complicate the apparatus layout, reduce the reliability of the equipment and also substantially increase the dimensions of the process areas.
- 30

The problem on which a first aspect of the invention is based, therefore, is to provide apparatus for use in the dissolution of nuclear fuel pins in which the apparatus can reliably be used to dissolve fuel contained in chopped cladding and to discharge hulls from the dissolver as well as require little maintenance and servicing, and which would not require  
5 a complicated apparatus layout or an excessive process area in the reprocessing plant.

The present invention provides a nuclear fuel dissolution apparatus comprising a perforated sloping ramp contained within a process chamber for containing solvent for the fuel and a pulsation member which in use creates pulses in solvent in the process  
10 chamber, the perforations being designed to direct pulses of solvent along and up the ramp, and a method comprising loading solvent into the process chamber, loading fuel pin pieces onto a lower region of the ramp and creating solvent pulses to transport the fuel pin pieces up the ramp to a discharge point where the cladding hulls are discharged from the ramp.

15 In preferred apparatus the ramp is spiral; the gradient of the spiral is preferably between 1 and 30 degrees and more usually between 1 and 20 degrees. Preferably, the process chamber is annular in cross section.

20 The gradient of the spiral in an upper zone of the process chamber may be greater than in a lower zone.

It is most preferred that the ramp is made out of flat blades, in which case the perforations of the ramp comprise inclined slits formed between the blades.

25 Preferably the angle between the plane of the blades and the horizontal is between 10 and 60 degrees.

In practice, the apparatus must be designed to have a so-called "eversafe geometry", that  
30 is, to avoid a critical mass of material collecting which allows a self-sustaining fission reaction. For this reason, the apparatus will in practice be designed to control the total amount of fissile material which can accumulate in any one place and/or the geometry in

which such accumulated fissile material is held. It is preferred for criticality reasons for the fissile material (chopped fuel pins) to be in elongate form rather than spherical. In a particular version of the method, each pair of adjacent blades makes a slit having a length (the dimension in the radial direction in the case of a spiral ramp in an annular chamber) of no more than 10 times the diameter of a fuel pin; such a design helps avoid an excessive accumulation of chopped fuel pins in the slit. More preferably, the slit length is between 5 and 10 times the diameter of a fuel pin.

In some embodiments the blades are made in the form of a trapezium and are fastened by the smaller end to a central blade support within the process chamber.

Preferred apparatus involves one or both of the features that the average width of the blades (extent of slit channel) is between 3 and 5 times the distances between them and that the distance between the plates at the outside wall of the container is 0.4 to 0.8 times the fuel pin diameter.

Preferably, the pulsation member comprises a pulsation chamber located coaxially within the process chamber. Normally, a neutron absorber is arranged between the pulsation chamber and an inside wall of the annular container.

In a particular version of the invention, the pulsation chamber, usually made in the shape of a cylindrical container, is located coaxially within the process chamber (which is usually annular) and communicates with a lower part of the process chamber by a an upwardly and outwardly directed duct (usually an annular slit). In preferred classes of the invention, a neutron absorber is situated between the pulsation chamber and an inside wall of the annular container.

The invention in another aspect provides an apparatus for the treatment of solid articles by liquid, comprising a container having an outer side wall of circular cross section, a spiral ramp located in the container, and a pulsator communicating with a lower part of the container, and also pipe connections for feeding in and removing pieces of fuel pin, solution and gas, characterised in that the ramp is made up of flat blades placed one after

another along the spiral and forming between one another inclined slit nozzles. Such apparatus is particularly suitable for the chemical treatment of solid phase articles larger or heavier than the wood chips with which is concerned the prior art spiral pulsed fluid apparatus.

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Usually, the process chamber of either aspect has an inner side wall as well as the inevitable outer side wall. The ramp in such chambers normally extends between the inner and outer side walls of the process chamber

- 10 The present invention also provides a method of dissolving fuel in chopped nuclear fuel pins in an apparatus comprising a perforated sloping ramp contained within a process chamber for containing solvent for the fuel and a pulsation member which in use creates pulses in solvent in the process chamber, the perforations being designed to direct pulses of solvent along and up the ramp, the method comprising loading solvent into the process
- 15 chamber, loading fuel pin pieces onto a lower region of the ramp and creating solvent pulses to transport the fuel pin pieces up the ramp to a discharge point where the cladding hulls are discharged from the ramp. The method may be performed in the reprocessing of nuclear fuel, the method further including reprocessing the dissolved fuel to form a fissile material optionally in the form of a fuel pellet, a fuel pin or a fuel assembly.

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The present invention is further described below by way of example only with reference to apparatus for dissolving the spent fuel of chopped fuel pins. It will be understood, however, that the invention may be applied to the fluid treatment of solids other than fuel pin pieces. The apparatus is illustrated non-limitatively by the accompanying drawings, in

25 which:

Fig. 1 gives a general view of the apparatus for dissolution showing a cross-section and the appearance of the ramp made up of blades fitted one after the other along the spiral;

Fig. 2 shows a cross-section of the apparatus along line A-A of Fig. 1;

- 30 Fig. 3 is an enlarged view of fragment A in Fig. 1 of the internal cylindrical shell of the annular container of the apparatus with ramp blades fitted on it;

Fig. 4 shows fragment B of the ramp from Fig. 1;

Fig. 5 shows fragment C of the ramp from Fig. 2; and

Fig. 6 shows the shape of the blades in the form of a rectangular (a) and isosceles (b) trapezium.

5 Fig. 1, therefore, illustrates a nuclear fuel dissolution apparatus which comprises a perforated sloping ramp (19) contained within a process chamber (1) for containing solvent for the fuel, a pulsation member (9) which in use creates pulses in solvent in the process chamber (1), the perforations (7) being designed to direct pulses of solvent along and up the ramp (19), and a discharge point (18) for fuel hulls disposed at an upper region  
10 of the ramp.

More particularly, the apparatus shown is for leaching of fuel in fuel pin pieces and comprises an annular reaction container (1), formed by internal (2) and external (3) cylindrical shells, and also a drain (4) and a cover (5). In the annular container (1) are  
15 blades (6) fitted one after another along a spiral between the internal (2) and external (3) walls of the container at a distance not exceeding the diameter of the fuel pin. (It will be appreciated that an apparatus of the invention cannot be used to treat articles able to fall between the blades (6)).

20 The blades form a spiral ramp for upwards movement of pieces of fuel pin upon pulsation of solvent (nitric acid in the Purex process) in the annular container (1). Each pair of adjacent blades (6) (see Fig. 3) forms an inclined slit nozzle (7). The gradient " $\alpha$ " of the spiral is between 1 and 20 degrees, and the angle " $\beta$ " between the plane of the blades and the horizontal surface is between 15 and 60 degrees.

25 The annular container (1) (see Fig. 1) communicates, in this case through an inclined conical slit (8) and the drain (4), with a pulsation chamber (9). In the illustrated embodiment the pulsation chamber is cylindrical and is situated coaxially with the annular container (1); it is equipped in its lower part with an outlet, normally a pipe connection  
30 (10), to empty the apparatus. The pulsation chamber (9) communicates, in this case via a pipe connection (11), with a pneumatic pulsator (not shown in Fig. 1), and a plate damping device (12) or other damping device is situated inside the chamber to ensure that

liquid in the chamber moves without waves or splashing. In the annular gap between the container (1) and the pulsation chamber (9) is a neutron absorber (13) to ensure nuclear safety while nuclear fuel leaching is going on. The neutron absorber (13) is of course dispensed with in non-nuclear applications.

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Suitable fluid inlets and outlets are provided for treatment liquid and for gas. Thus, the illustrated apparatus includes pipe connections to feed in solution (14) and blow off gases (15) connected to the upper part of the annular container (1). An inlet for the solid phase material (in this case pipe connection (16) to feed in pieces of fuel pin with nuclear fuel) is connected to the lower part of the annular container (1). A pipe connection (17) is connected to pipe connection (16) to remove solution from the leaching apparatus; alternatively another solution outlet may be provided. A discharge point is provided for the discharge of fuel hulls from the top of the ramp (19); specifically, a pipe connection (18) is connected to an upper part of the container (1) to remove the tubular fuel hulls after dissolution of the fuel

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In one embodiment of the pulsation apparatus, the gradient of the spiral in an upper part of the annular container (1) is greater than in a lower part. Thus, for example, the gradient of the spiral in the lower and middle parts of the apparatus may be set at 2 degrees, and in the upper part at 4 degrees. This enables the time spent by the pieces in the apparatus to be extended for fuel pin pieces in which, for one or another reason, there has not been full leaching of the fuel. Since such pieces are of greater mass, an increase in the gradient of the spiral leads to a slowing of their movement towards the zone of discharge from the apparatus.

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In another embodiment, the blades (6) (see Fig. 6) are made in the form of a trapezium and are fastened by their smaller end on the inside wall (2) of the annular container (1). This enables the optimum angle of the guide surface of the helical ramp towards the axis of symmetry of the apparatus to be obtained to compensate for centrifugal forces on the fuel pin pieces when the pulsation jets act on them to be compensated.

30

In another version of the invention, the width of the blades (6) is between 3 and 5 times the distances between them. This enables flat jets of the liquid phase to be formed with pulsation of liquid in the annular container, to move the layer of fuel pin pieces upwards along the spiral guide ramp. Irrespective of the blade width, the distance between the  
5 blades (6) at the outside wall of the container is suitably 0.4-0.8 times the external diameter of the fuel pin. This ratio of sizes prevents blockage of the slits by fuel pin pieces, and reduces the hydraulic resistance of the apparatus and pulsation energy losses.

The apparatus operates as follows. The annular container (1) and the pulsation chamber  
10 (9) are filled with fuel leaching solution, which comes in through the pipe connection (14). The feed of sheared fuel pin pieces, which takes place over a set time, is via the pipe connection (16) onto the lower section of the spiral ramp formed by the blades (6). Pneumatic pulses from the pulsator (not shown in the Figures), which have set parameters for gas pressure, frequency and shape of oscillations along the pipe (11) (see Fig. 1), enter  
15 the pulsation chamber (9). Under the influence of these pulses, the solution filling the pulsation chamber (9) and the annular container (1) moves in an oscillating (reciprocal) fashion at a set frequency, amplitude and pulsation shape. The level damper (12) which is in the pulsation chamber (9) ensures that the solution moves without waves or splashing.

20 These oscillations are transferred via the slit channel (8) to the solution in the annular container (1). Passing through the slit nozzles (7) formed by the blades (6) (see Fig. 3) of the spiral ramp, the solution forms flat pulsation jets. When the solution in the annular container (1) moves upwards under the influence of these jets, the fuel pin pieces are taken away from the surface of the spiral ramp formed by the blades (6) and move along  
25 and up it by a certain distance. When the compressed gas is released from the pulsation chamber (9) into the blow-off, the solution in the annular container (1) moves downwards through the static difference in levels in the annular container (1) and the pulsation chamber (9). This makes the solution press the fuel pin pieces to the blades (6) of the ramp, and they move no further along the ramp until the next pulse. In subsequent  
30 pulsation cycles, the process is repeated and the fuel pin pieces gradually move along the spiral ramp in an upward direction. Moving along the spiral ramp, the fuel pin pieces

gradually rise upwards through the apparatus and at the end of the ramp they pass out of the apparatus via the pipe connection (18), along with a certain quantity of solution.

5 Fresh solution entering the annular container (1) via the pipe connection (14), moves towards the fuel pin pieces, dissolving the fuel contained in them, and leaves the apparatus through a pipe connection (17), which is connected to the loading channel (16). To remove gases formed during the process of spent fuel dissolution, a blow-off pipe is provided on the cover (5) of the annular container (1). As the fuel dissolves in the fuel pin pieces, their mass diminishes, and their rate of movement along the ramp rises. To  
10 reduce the rate of movement of the fuel pin pieces in which fuel still remains, the design of the apparatus envisages an increase in the gradient of the spiral ramp in the upper part of the apparatus.

15 The invention in preferred embodiments provides pulsation apparatus having the combination of spatial and geometric characteristics which will give the most effective hydrodynamic conditions for stable movement of pieces of sheared fuel pin up the spiral in the annular space with fuel pieces having a length to diameter ratio of between 1:1 and 6:1 while preventing criticality in the apparatus and giving it a high output

20 The method of the invention is typically performed in the reprocessing of nuclear fuel, the method further including reprocessing the dissolved fuel to form a fissile material optionally in the form of a fuel pellet, a fuel pin or a fuel assembly.

25 In another embodiment of apparatus in accordance with the present invention, the welded together blades of the above described embodiment are replaced by a single plate having transverse elongate slots located therein.

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## REVISED CLAIMS

1. A nuclear fuel dissolution apparatus which comprises a perforated sloping ramp (19) contained within a process chamber (1) for containing solvent for the fuel, a pulsation member (9) which in use creates pulses in solvent in the process chamber (1), the perforations (7) being designed to direct pulses of solvent along and up the ramp (19), and a discharge point (18) for fuel hulls disposed at an upper region of the ramp characterised in that the ramp (19) is made out of flat blades (6) and the perforations (7) of the ramp (19) comprise inclined slits formed between the blades (6).
2. An apparatus of claim 1 in which the ramp (19) is spiral.
3. An apparatus of claim 1 or claim 2 in which the process chamber (1) has an outer side wall which is circular in cross section.
4. An apparatus of any of claims 1 to 3 in which the gradient of the spiral is between 1 and 30 degrees.
5. An apparatus of claim 4 in which the gradient is between 1 and 20 degrees.
6. An apparatus of any of claims 1 to 5 in which the gradient of the spiral in an upper zone thereof is greater than in a lower zone.
7. An apparatus of claim 1 in which the angle between the plane of the blades and the horizontal is between 10 and 60 degrees.
8. An apparatus of claim 1 or claim 7 in which the inclined slits are no more than 10 fuel pin diameters in length.
9. An apparatus of claim 1 in which the blades (6) are made in the form of a trapezium and are fastened by the smaller end to a central blade support within the process chamber (1).

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10. An apparatus of claims 1 in which the average width of the blades (6) is between 3 and 5 times the distances between them.
11. An apparatus of claim in which the distance between the plates at the outside wall of the container is 0.4 to 0.8 times the fuel pin diameter.
12. An apparatus of claim 1 in which the pulsation member (9) comprises a pulsation chamber disposed centrally within the process chamber (1).
- 10 13. An apparatus of claim 12 in which a neutron absorber is arranged between the pulsation chamber (1) and an inside wall of the annular container.
14. An apparatus of any of claims 1 to 13 which is performed in the reprocessing of nuclear fuel, the method further including reprocessing the dissolved fuel to form a fissile material optionally in the form of a fuel pellet, a fuel pin or a fuel assembly.
- 15 15. An apparatus for the treatment of solid articles by liquid, comprising a container having an outer side wall of circular cross section, a spiral ramp (19) located in the container, and a pulsator (9) communicating with a lower part of the container, and also pipe connections for feeding in and removing pieces of fuel pin, solution and gas, characterised in that the ramp (19) is made up of flat blades (6) placed one after another along the spiral and forming between one another inclined slit nozzles and the perforations (7) of the ramp comprise inclined slits between the blades (6).
- 20 16. An apparatus of claim 15 in which the gradient of the spiral is between 1 and 30 degrees.
17. An apparatus of claim 16 in which the gradient is between 1 and 20 degrees.
- 30 18. An apparatus of any of claims 15 to 17 in which the angle between the plane of the blades and the horizontal plane is between 15 and 60 degrees.

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19. An apparatus of any of claims 15 to 18 in which the gradient of the spiral in an upper zone thereof is greater than in a lower zone.

20. An apparatus of any of claims 15 to 19 in which the blades (6) are made in the form of a trapezium and are fastened by the smaller end to a central blade support within the process chamber (1).

21. An apparatus of any of claims 15 to 20 in which the average width of the blades is between 3 and 5 times the distances between them.

10

22. An apparatus of any of claims 15 to 21 in which the pulsation member comprises a pulsation chamber (9) disposed coaxially within the process chamber (1).

15

23. A method of dissolving fuel in chopped nuclear fuel pins in an apparatus according to claim 1.

20

24. A method according to claim 23 wherein the apparatus comprises a perforated sloping ramp (19) contained within a process chamber (1) for containing solvent for the fuel and a pulsation member which in use creates pulses in solvent in the process chamber (1), the perforations being designed to direct pulses of solvent along and up the ramp, the method comprising loading solvent into the process chamber (1), loading fuel pin pieces onto a lower region of the ramp and creating solvent pulses to transport the fuel pin pieces up the ramp to a discharge point where the cladding hulls are discharged from the ramp.

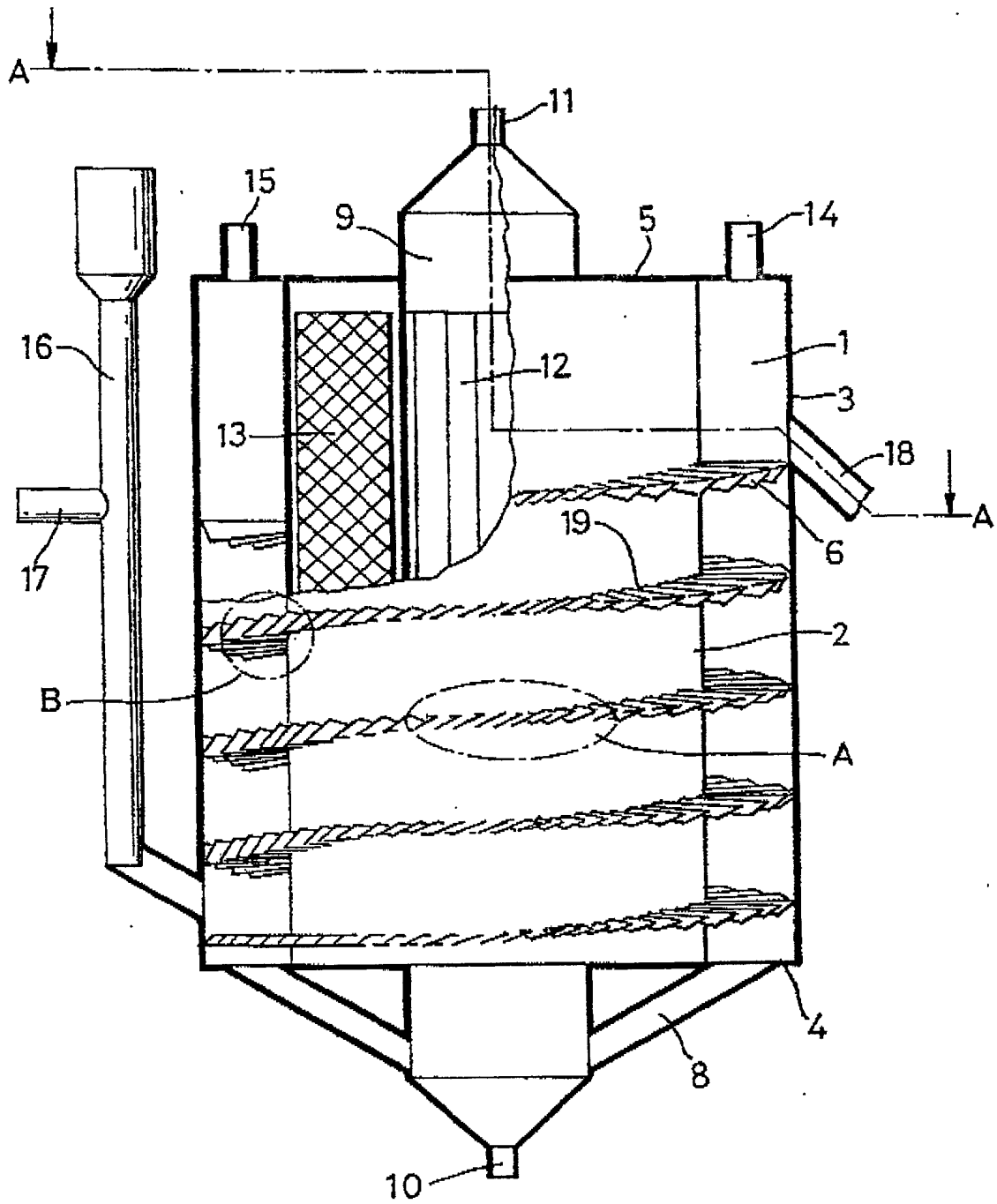
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25. A method of claim 23 which is performed in the reprocessing of nuclear fuel, the method further including reprocessing the dissolved fuel to form a fissile material optionally in the form of a fuel pellet, a fuel pin or a fuel assembly.

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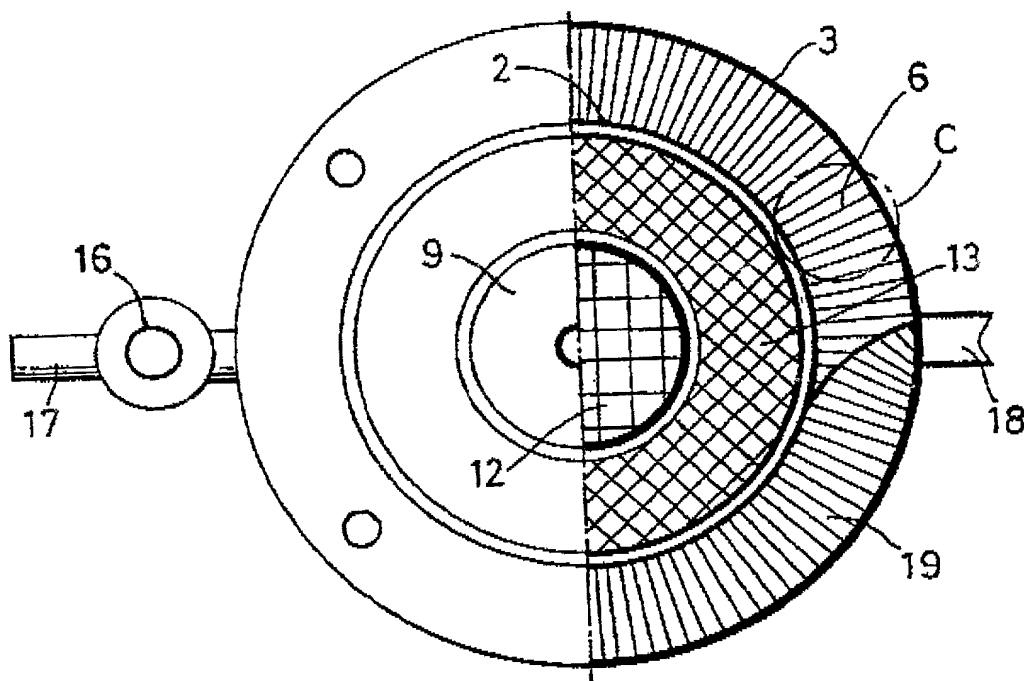
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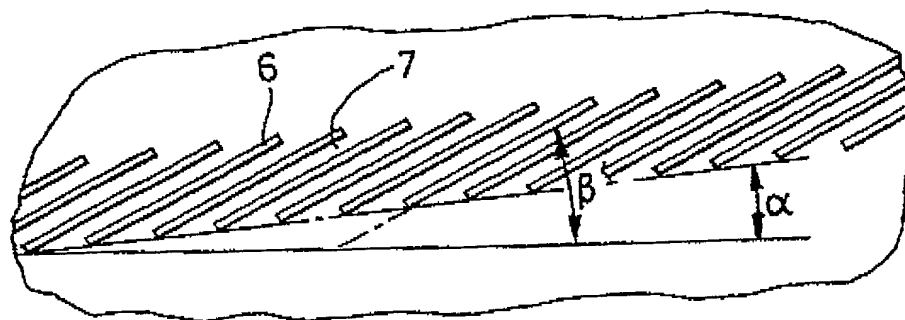


**Fig. 1**

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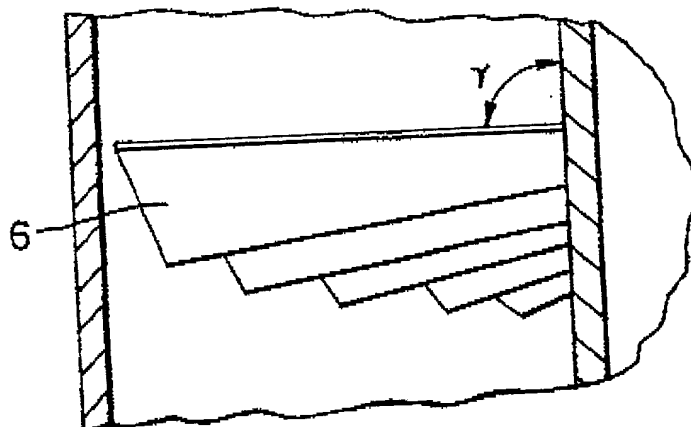
**Fig. 2**



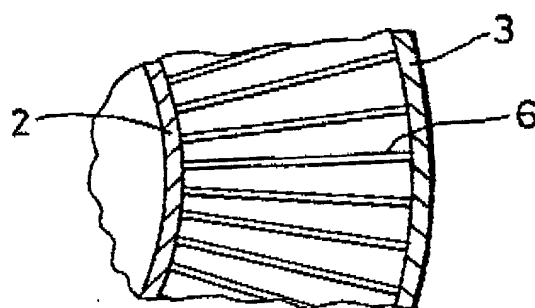
**Fig. 3**

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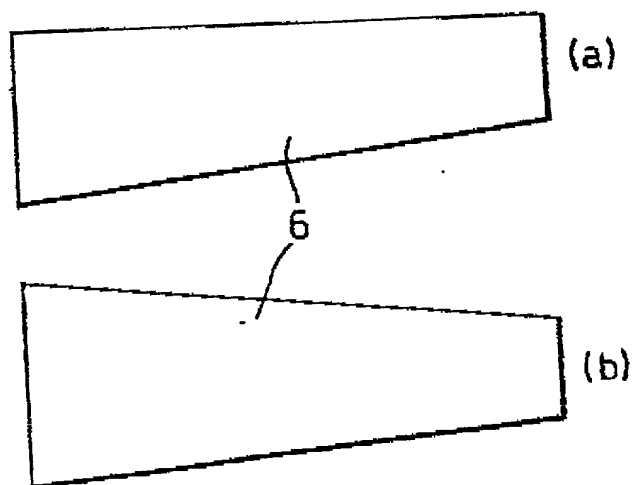
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**Fig. 4**



**Fig. 5**



**Fig. 6**

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# DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

Attorney Docket No. 9052-70

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled, **APPARATUS FOR DISSOLVING NUCLEAR FUEL**, the specification of which

☒ was filed on June 3, 1999 as PCT International Application No. PCT/GB99/01537. ✓

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37 Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, § 119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate, or § 365(a) of any PCT International application which designated at least one country other than the United States of America, listed below and have also identified below any foreign application for patent or inventor's certificate, or of any PCT International application having a filing date before that of the application on which priority is claimed.

98110181 ✓	Russia ✓	06/03/1998 ✓	<input checked="" type="checkbox"/> Yes <input type="checkbox"/> No
Number	Country	MM/DD/YYYY Filed	Priority Claimed

			<input type="checkbox"/> Yes <input type="checkbox"/> No
Number	Country	MM/DD/YYYY Filed	Priority Claimed

I hereby claim the benefit under Title 35, United States Code, § 119(e) of any United States provisional application(s) listed below.

None	
Application Number(s)	Filing Date (MM/DD/YYYY)

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) or § 365(c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application(s) in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application (37 C.F.R. § 1.63(d)).

PCT/GB99/01537 ✓	06/03/1999 ✓	Published
Appln. Serial No.	Filing Date	Status Patented/Pending/Abandoned

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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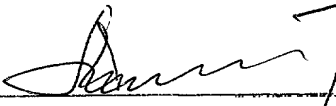
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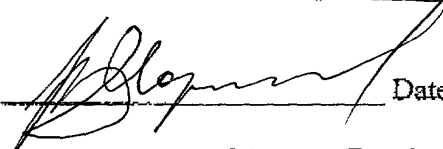
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